same series we have also "Minnesota Mushrooms," by Professor Clements.

A year ago A. O. Garrett, of the Salt Lake City High School, published a little book of 106 pages, entitled "Spring Flora of the Wasatch Region," and including "the eastern edge of the Great Basin as far south as Manti" (central Utah). This is now followed with a second, considerably enlarged edition of 139 pages. It must be very useful to pupils in the schools of the region covered. It would be still more helpful if not confined to "spring plants" alone ("before June 15").

Much like the last is the "Spring Flora of the Intermountain States," by Professor Dr. Aven Nelson, of the University of Wyoming (Ginn), which in 202 pages covers Colorado, Wyoming, Montana, Idaho (excepting the northern part), a portion of eastern Oregon and the northern half of Utah. The treatment is much like that in the Wasatch Flora, and must be equally useful in the much larger region included. Here again one wishes that the "spring" limit could be removed.

Hall's "Yosemite Flora" (Elder, San Francisco) is a book designed to appeal in paper, pictures and binding more to the tourist than to the pupils in schools, and yet it must prove a most inspiring field manual for pupils fortunate enough to have access to its keys and descriptions. While called a Yosemite Flora, we are told that it is also "designed to be useful throughout the Sierra Nevada Mountains." Eleven most artistic plates and 170 text figures add much to the usefulness of the book for the beginner.

The "Flora of Nebraska," published by N. F. Petersen, instructor in botany in the Louisiana State University, is an attempt to name every plant (conifers and flowering plants) growing without cultivation in the state. It is modeled after Rydberg's well-known "Flora of Colorado," and like it the treatment is by the copious use of keys, by means of which the phyla, classes, orders, families, genera and finally the species are successively found. And after the species is determined by this method one finds a little paragraph assigned to it containing habitat, distribution and locality data. It will be useful to high-school pupils, in spite of the rather numerous typographical errors, due to the employment of a printer unaccustomed to scientific printing.

Here may be mentioned Professor Schaffner's "Key to the Families of Seed Plants" designed to aid his students (Ohio State University) to distinguish the natural plant families by carefully devised keys.

BOTANY IN THE MOUNTAINS

The University of Colorado Mountain Laboratory at Tolland, Colo., will hold its session this year, beginning June 24 and ending August 2, 1912. There will be a general course in field biology, in which both animals and plants are considered in relation to their environment, and also courses in systematic botany, ecology and biology of ponds and streams. Special attention will be given to research work.

The laboratory is situated in an interesting region at an altitude of nearly 9,000 feet. Tolland is the station for Boulder Park, a mountain valley surrounded by timber-clad hills. Within easy reach of the laboratory are typical pine and spruce forests, mountain meadows, narrow canyons, glacial lakes and alpine tundra. In addition to regular daily field trips which take the student to these various habitats of animals and plants there will be all day excursions by rail to the foothills and even to the plains for the purpose of making comparative studies of the flora and fauna of these localities. Professor Francis Ramaley, of the University of Colorado (Boulder), is the director of the laboratory.

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SPECIAL ARTICLES

NITRATES IN SOILS[1]

THE fertilizing value of materials that we now know to contain nitrogen was of course

[1] Paper read by invitation before the Society of American Bacteriologists at Washington, December, 1911.

recognized very early, though nitrogen was first recognized as a distinct element in 1772 by Rutherford.

Later it was demonstrated that nitrogen is an element indispensable to life, present in all organisms and the mass of literature, scientific, popular and commercial, concerning nitrogen in its various forms and their relation to plant growth is overwhelming to the student.

Yet, notwithstanding the long period of time during which we have recognized the importance of nitrogen, the aggregate of many life times that have been devoted to its study or the thousands of pages that have been published concerning its relation to plants, there still remain some of the most fundamental questions for solution.

The universality of nitrogen in plants is well authenticated. The amounts removed from the soil by a few leading crops are as follows:

Corn (45 bushels per acre)	63 lbs.
Cabbage (15 tons per acre)	100 lbs.
Clover hay (2 tons per acre) ..	82 lbs.
Wheat (15 bushels per acre) ...	31 lbs., etc.

Not only is it present, but it is indispensable, as has been repeatedly shown by careful water- or sand-culture experiments. Just how and why nitrogen is essential is a much more difficult question. It is a necessary element in the composition of protoplasm, and many other organic substances. It aids in the assimilation of other needed elements, and in photosynthesis. These functions of nitrogen would account for the need of a certain amount of available nitrogen in soils used for crop production. But it is found that soils with apparently an abundance of available nitrogen for the supply of many crops are benefited by the addition of still more nitrogen. Various theories which we will not enter upon here further than to point out that nitrogen or its compounds may serve other uses than by being merely absorbed or absorbed and assimilated have been proposed to explain this peculiar fact. What these other uses are is one of the large questions, as yet barely disclosed. Whatever other uses nitrogen may serve, that of a food element is unquestionably a preeminent one, and it is with this phase of the nitrogen subject alone that I shall deal.

Admitting the importance of nitrogen in assimilation the next question is: "In what forms is nitrogen available to the plant?" This, as has been the fate of many questions in biology, received its emphatic answer years ago, an answer that asserts itself convincingly through thousands of popular and scientific articles and text-books, but one which seems to be founded on very insecure evidence and one which is likely to be largely modified as research progresses.

The popular, almost the universal conception of available nitrogen is expressed in some such words as these, which are taken from prominent texts by famous authors and mostly from recent works.

> The majority of farm crops can use only that part of the nitrogen in the soil that is present as nitrate[1]

and on a later page:

> The plant can make use of the nitrogen only in the form of nitrates.
>
> The nitrates are the chief source of the nitrogen supply of green plants.[2]
>
> Sulphate of ammonia . . . must be nitrified before the nitrogen is available to plants.[3]
>
> The conversion of the ammonia formed during the process of putrefaction into the nitrates is a matter of greatest importance in soil fertility. . . . A soil to encourage nitrification must, then, have suitable basis. The question of soil fertility is, then, in its last analysis a bacteriological problem.[4]

This conception of nitrates has inevitably focused attention on nitrates as a soil factor of preeminent, of indispensable importance. It makes them appear so valuable that their coming and going are of superlative import and their failure to attend to spell disaster.

The subject assigned to me is "Nitrates in

[1] Vivian, 1909.

[2] Bergen and Davis, "Principles of Botany," pp. 233.

[3] Percival's "Agricultural Bacteriology," p. 142.

[4] Frost and MacCampbell, "General Bacteriology," 1910, p. 288.

Soils." I shall consider this subject under several heads as follows, setting aside purely physical and chemical phenomena and limiting myself to the biologic aspects of the question.

The origin of nitrates in soil nitrification and nitratation.

The destruction of nitrates in soil denitrification.

Methods.

The actual importance of nitrates.

Nitrification consists in the conversion of ammoniacal nitrogen into nitrites then nitrates, processes shown by the classic work of Winogradsky to be dependent on two separate groups of bacteria, the nitrite and the nitrate bacteria. Winogradsky's work has been abundantly confirmed and is not to be questioned. And so far as we know yet all nitrification results from this dual activity, the several reports that have been made of direct nitratation of organic nitrogen or of ammonia by bacteria lacking proper confirmation.

Ammonia is thus essential to nitrate formation and ammonification of organic nitrogenous substances is an essential preliminary step. Ammonifying bacteria are of numerous species, indeed some years ago in my laboratory a long search for soil bacteria that could not ammonify ended in failure. Ammonification in the light of present knowledge appears to be an absolutely essential process in the circulation of nitrogen, but the need is amply met and in no soil that I know of, and we have ourselves examined many hundreds, is there any actual deficiency in ammonifying power.

Recently the Rothamsted Station has attributed low yields to low ammonifying power due to consumption of ammonifying bacteria by predatory protozoa. This condition may exist in exceptional cases, but that it is in any wise general is not probable.

Nitrifying organisms have generally also been assumed to be present practically everywhere and in ample numbers. The results of a Bacterial Soil Survey conducted in my own laboratories and about to be published show that this assumption is not warranted. In a large per cent. of the soils tested the N.E. was very low. It appears, therefore, that while a deficiency in ammonification is not to be feared there may be instances, perhaps many of them, where the amount of nitrification falls below that of the nitrogen equivalent of a good crop. Why nitrification is vigorous in some soils and very poor in others is not known. In some instances it may be referred to unfavorable acidity, moisture, etc. Many cases are due to causes as yet unknown. That abundance of organic matter does not inhibit nitrification was clearly demonstrated in our own experiments, in which vigorous nitrification occurred in pure cow manure.

On the other hand, an exceptional case of injury from too great nitrification has recently been reported by Sackett.

Dentrification is the destruction of nitrates. It is brought about by many species of bacteria and may result in reduction of nitrates, to ammonia, various oxides or even to free nitrogen. This is unquestionably a detrimental process if it proceeds below the ammonia stage. The conditions necessary to denitrification are usually stated to be the proper organisms, moisture and organic matter. The organism is conceded to be commonly, almost universally present. Yet the fertilizer formulæ of the chemist and agricultural teacher usually call for an admixture of nitrates with dried blood, cottonseed meal, etc., thus surely furnishing ideal conditions for denitrification. Theory here opposes practise and as yet no decisive experiments have shown which is correct.

Methods.—I can not refrain in passing from referring to the absolute necessity in soil bacteriological work of making the tests in soils and not in solutions. Winogradsky found that in solutions organic matter inhibited nitrification. From this he and others have generalized that it does so in soil, a conclusion that is far from the truth, as our experiments have conclusively shown.

THE ACTUAL IMPORTANCE OF NITRATES

In all of the foregoing discussion we have assumed that nitrates are the necessary or at

least by far the most readily utilized form of nitrogen. The vast amount of research carried on in many laboratories regarding the processes of nitrification and dentrification indicate that these phenomena are regarded as of high significance and nitrogen of superlative value. Is this so?

Nitrogenous organic matter may be classified as proteids, albuminoids, amides and alkaloids. The larger part of the organic nitrogen in soils probably consists of acid-amines and amino and amino-acids.

To what extent may these or their degeneration products, particularly ammonia, serve as plant food?

A few years ago most special students and perhaps all general writers would have said that these substances must undergo nitrification before they are available to plants. To-day, without much evidence, perhaps without any evidence that will stand searching criticism, there is a tendency among some writers to hedge on this point and to speak of ammonia as well as nitrates as possessing available nitrogen. We even hear the term "active nitrogen" embracing ammonia and nitrate nitrogen.

The evidence on this question is too voluminous to bring before you, but we may summarize it something as follows:

Innumerable experiments have been made bearing upon the relative availability of nitrate and ammonia nitrogen to plants. Most numerous of such have, of course, been field tests of ammoniacal compounds and of nitrates drawing conclusions from the yield or the crop analyzed. Such tests are manifestly inconclusive, since in all cases the question of nitrification in the soil is an ignored factor and it is not in reality known whether the ammonia that is applied to the soils is used as such or is first nitrified or indeed whether the reverse may not be true, viz., that the nitrates have been reduced to ammonia and utilized in that form. The general conclusion that can be drawn from such experiments is that ammonia applied to soils does not, with most crops, on most soils, give so large crop returns as do nitrates. The common ratio of utility is generally given as something like 60 or 70 to 100. This conclusion varies, however, for different crops, different soils, different times; and such experiments are far from giving a solution of the fundamental question.

Another line of attack is by means of water-culture experiments. Many such lack bacteriological control and the conditions regarding nitrification are not known. A few have been conducted with rigid bacteriological control and do actually prove that a plant can assimilate ammonia without its previous nitrification. Such tests, however, do not simulate field conditions much more closely than would experiments on the habits of squirrels parallel nature if conducted in aquaria. Our results of comparative tests of the functions of bacteria in soils and in solutions have given us entire lack of faith in such abnormally conditioned experiments.

Again, plants have been grown in sterile soils under aseptic conditions, with constant and rigid chemical and bacteriological control. Such results may properly pose as qualitative. But they are not quantitative, because of necessity they are conducted on but a few plants and the factor of individual variation is so great that quantitative results are vitiated unless a sufficiently large number of plants be used to reduce the coefficient of error to something like a negligible quantity. Also the conditions of control involving abnormal radiation, ventilation, etc., are unsatisfactory.

Jost says:[5]

> Many hundred culture experiments in water and sand have established the fact that nitric acid forms an excellent, not to say the best possible source of nitrogen for the great majority of plants. (How the divergent results arrived at by Treboux (1905) are to be explained it is, as yet, impossible to say.)
>
> The recent comprehensive researches of Pitsch (1887–1896) and of Mazé (1900) have conclusively proved that the nutritive value of ammonia must not be entirely denied; in the majority of green plants it is second only to nitric acid in value.

[5] Jost's "Plant Physiology," pp. 134 and 135.

In the case of some plants, particularly maize and other Gramineæ, ammonia is by no means of inferior value to nitric acid, for Mazé was able to obtain as great an increase in dry weight in maize, using at most a one half per cent. solution of ammonium sulphate, as when he supplied it with a solution of a nitrate. Similar results were obtained in cultures of *Brassica* and species of *Allium*. Forest trees also must be dependent on ammonia, since nitrates are seldom present in woodland soils.

So far as we know at present it is quite certain that in addition to plants which definitely prefer nitric acid (*e. g.*, buckwheat, potatoes, turnips) there are others which get on just as well or even better with ammonia.

Perhaps after all the most conclusive proof that plants in nature can do well without nitrates comes from the fact that certain peat soils have been shown to be devoid of nitrates, yet they amply support plant growth. Again, rice responds well to ammonia even in soils where no nitrification can be detected.

Also it is true that we, as well as other investigators, have shown that soils very low in nitrification may be very productive and that on such soils plants respond readily to organic matter or ammonia, indicating that nitrification is often not an essential factor to soil fertility.

The general conclusion regarding the availability of ammonia and nitrate-nitrogen is that both can be used by many plants; that often nitrate nitrogen applied in the field gives larger crop yields. But the relative availability of these nitrogenous substances for crop plants under natural conditions has not yet been determined. This is an essential desideratum. A question that must be answered conclusively before we can know the significance of nitrification and dentrification.

It seems after all that ammonification is the essential thing and that nitrification is relatively unimportant, but this is only indicated, not proved.

There is need of rigid proof as to the relative availability to each crop plant of ammonia and of nitrate nitrogen. Then we shall know the true importance of the problems of nitrification and of denitrification. Following this knowledge will come the questions of correcting such evils as need correction, the heightening of nitrifying power in cases where this is low and where higher nitrification would be of advantage; the lowering of denitratation if this be a disadvantage and where it is a disadvantage.

Plant physiology must join hands with soil bacteriology to ascertain which are the significant problems that conditions of deficiency may receive correction.

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REACTIONS OF YOUNG LOBSTERS DETERMINED BY FOOD STIMULI

IN recently glancing through some old notes written several years ago, when the writer was interested in problems relating to the behavior of the larval lobster (*Homarus americanus*), certain unpublished data regarding the reactions to food-stimuli came to light. It is the aim of the present note to give some of these data, which may be regarded as supplementary to the material published in 1908,[1] terminating the writer's investigations on the subject of behavior of *Homarus*.

Many students of animal behavior have learned that the condition of hunger is able to greatly modify the reactions of organisms to many stimuli—especially to food. Generally speaking, it has been found that hunger prevents the manifestation of certain normal types of reaction. The effect of hunger upon certain stages of *Homarus* is no exception to this rule. In this instance, however, the condition of hunger has been thus far found instrumental in modifying the reactions of the lobster only in the fourth and later stages, for similar experiments upon lobsters in the earlier stages have not yet been made. One reason for this is the fact that the larval lobsters of the first three stages are not able to direct their own activity in a definite direc-

[1] "The Behavior of the Larval and Early Adolescent Stages of the American Lobster (*Homarus americanus*)," *Journ. Comp. Neurol. and Psychol.*, 1908, 18, (3), 199–301.